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AN ALGORITHM FOR DATA SUBSTITUTION IN THE ON-LINE EXPERT SYSTEM OF KIDD CREEK MINES

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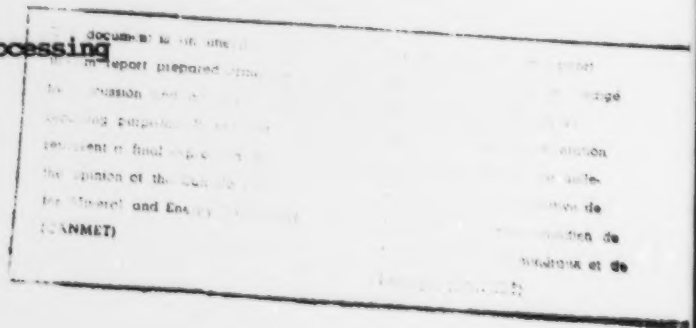

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AN ALGORITHM FOR DATA SUBSTITUTION IN THE ON-LINE EXPERT SYSTEM OF KIDD CREEK MINES

by

J.LEUNG* and D.LAGUITTON**

ABSTRACT

A joint project to design an expert system to improve reliability of assay information in a flotation plant was initiated in April, 1988 between CANMET and Kidd Creek Division, Falconbridge Limited, Timmins. The purpose is to increase the availability of assay data through substitution for erroneous data which can be identified by an on-line expert system. This paper discusses the data substitution strategy using a modified version of the MATBAL and SPLITX programs to calculate valid data. The two programs are directly executed from the knowledge base using Neuron Data's expert shell NEXPERT.

Keywords: Mineral Processing; Expert System; Material Balance; MATBAL software; SPLITX software; Split Coefficient; Data reconciliation.

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UN ALGORITHME POUR LE REMPLACEMENT DE DONNÉES ERRONNÉES DANS LE SYSTEME EXPERT DE COMMANDE AUTOMATIQUE DE KIDD CREEK MINES.

par

J.LEUNG* et D.LAGUITTON**

RÉSUMÉ

CANMET et Kidd Creek, une division de la compagnie Falconbridge Ltée, ont entrepris en avril 1988, un projet conjoint visant à mettre au point un système expert pour améliorer la fiabilité des données dans les circuits de flottation du cuivre et du zinc. L'objectif est de calculer des valeurs de remplacement pour les données qui ont été identifiées comme étant erronn es par un système expert. Ce rapport passe en revue la méthode de substitution qui est basée sur l'utilisation combinée d'une version modifiée de MATBAL et de SPLITX, deux programmes développés à CANMET. Ces programmes sont activés directement par la base de données du système expert basé sur NEXPERT, un système de NEURON DATA.

Mots clés: Minéralurgie; systèmes experts; bilan matière; logiciel MATBAL; logiciel SPLITX; coefficients de partage; filtrage des données.

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INTRODUCTION

The tests described in this report were performed to validate a data substitution procedure initially proposed by D.Laguitton to P.Thwaites of Kidd Creek Mines in 1987 to be implemented in the joint Expert System project between CANMET and Kidd Creek Mines(1). The data substitution procedure consists of using the split coefficients obtained from an execution of MATBAL(2) with valid assays to simulate invalid assays with the SPLITX(3) simulator, when the head stream assays are available. The delivery of the algorithm involved two main steps:

1) modification of MATBAL to calculate split coefficients of each assay type for each node (or unit) in the flowsheet
2) modification of SPLITX to replace the general flowsheet decomposition subroutines by a preset flowsheet definition corresponding to the Cu/Zn circuit at Kidd Creek.

The substitution algorithm is completely implemented by transferring split coefficients obtained from the modified MATBAL of step one, to the modified SPLITX of step two.

CHRONOLOGY

1) The modified source code to perform step one and step two was delivered to M.Burroughs of Kidd Creek in July, 1988. The substitution scheme was discussed with M.Burroughs and later with P.Thwaites in the meeting. All data specific to Kidd Creek was assigned within the code to simplify the data input requirements. For example, assay names, stream names, node equations, error model and program options were fixed. The only allowed variation in the input file for MATBAL was the table of stream assays. MATBAL would then produce three disk files containing flowrates, assays and split coefficients for the Cu circuit in the first file, those for the Zn circuit in the second file and the split coefficients alone for both circuits in the third file, so that the third file could be read directly by the modified SPLITX (Figure 1). A sample run data file which consists of 74 sets of Kidd Creek "B" division data sampled on April 6,1988 was also included in the same disk delivered to Kidd Creek. In the proposed substitution scheme, J.Leung suggested that when one or two streams contain invalid assays, they could be reconstructed by using MATBAL only and penalizing the error model of "intelligent" guesses for assays needing replacement. Such a scheme is possible due to the redundancy of assays that can be processed by MATBAL. The difference in results obtained with the CANMET version and Kidd Creek on-line version of MATBAL was discussed during the brief presence of J.Carriere. The listing of the on-line MATBAL was not available to CANMET at the time and no investigation of the reasons for the differences could take place.

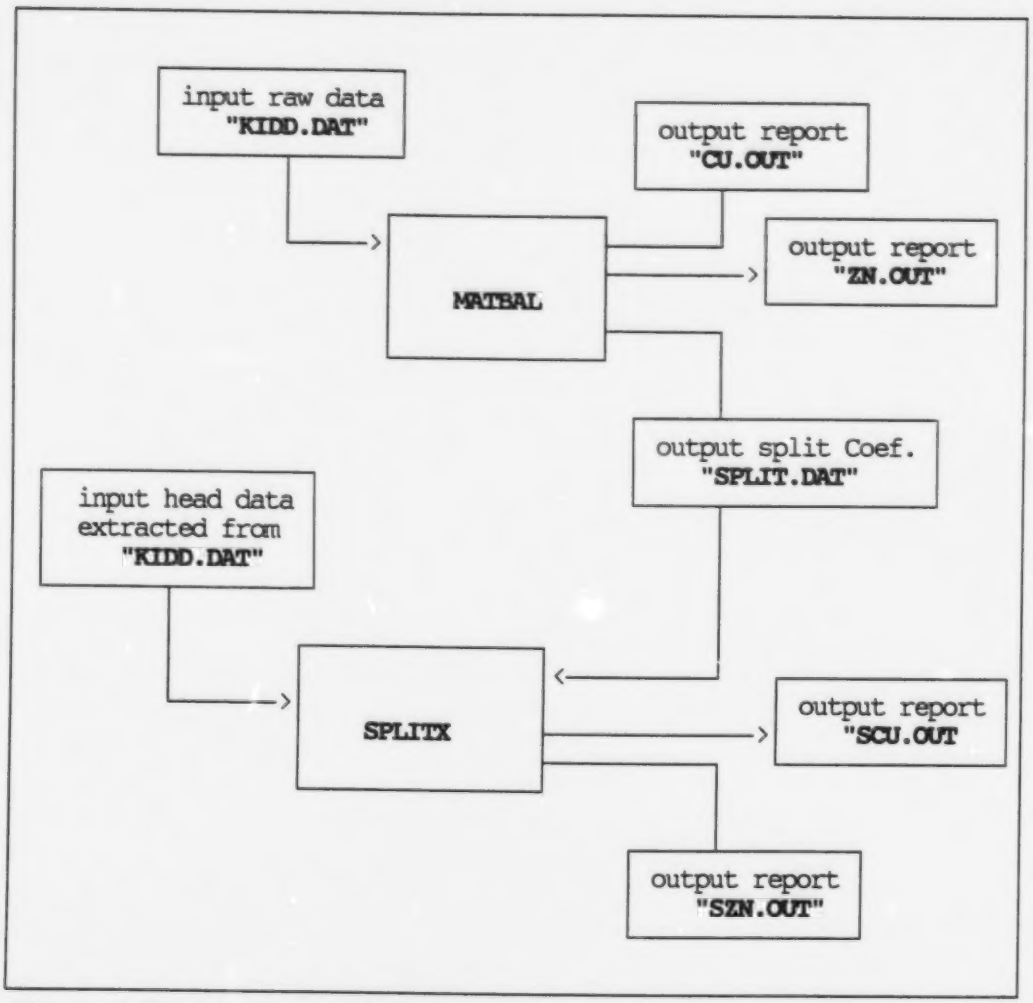

Figure 1 Structure of modified versions of MATBAL and SPLITX

2) A meeting was held in Kidd Creek on November 2,1988 mostly to initiate the drafting of a publication. The above algorithm was again discussed with M.Burroughs and J.Carriere who stressed the requirement that whenever possible, valid assays be used rather than simulated from a head sample. The part of the MATBAL code believed to have been modified at Kidd Creek was printed to be examined at CANMET.

3) A meeting was held at Timmins on November 23,1988 where J.Leung made another presentation of the algorithm, this time with a discussion of its interaction with the NEXPERT knowledge base (Figure 2). Technical discussions took place about specific values such as validity boundaries, error model penalty and values of the error model currently on-line at Kidd Creek. It was decided that further tests would be conducted to ascertain whether 2

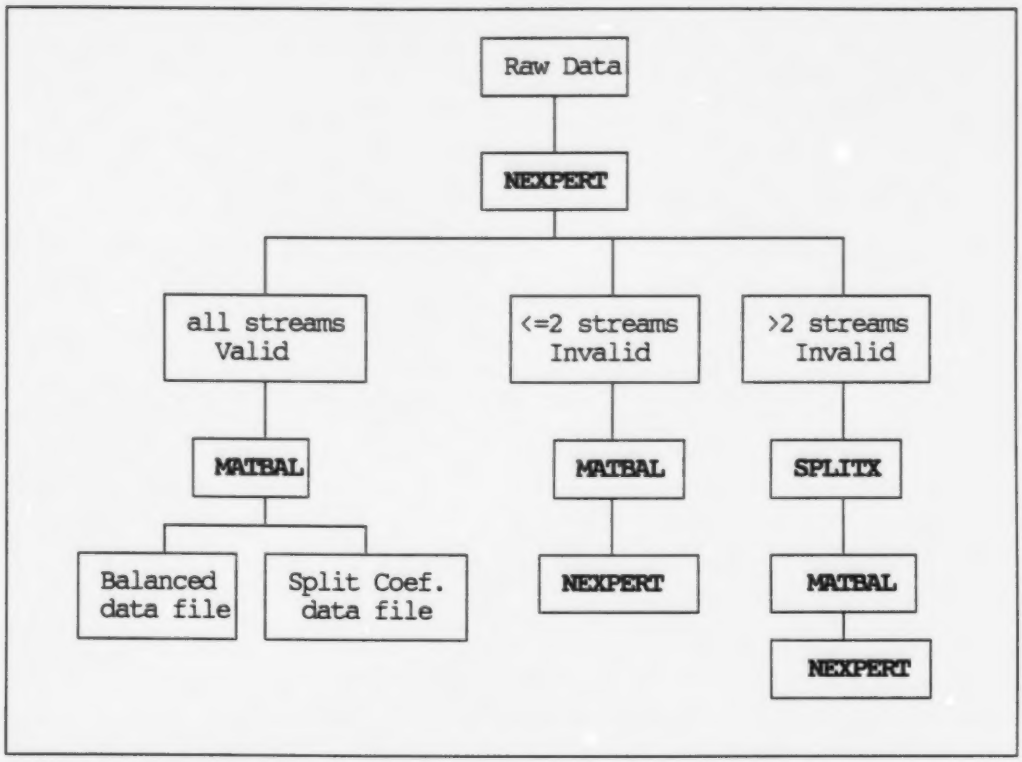

Figure 2 Interaction of MATBAL/SPLITX algorithms with NEXPERT knowledge base

streams contain invalid data, the "MATBAL only" scenario was robust enough. Also, a new level of validation was introduced, namely, if after substitution by MATBAL, the assays are still invalid, then, the SPLITX simulation route would be used (Figure 3). The error model penalty chosen at this meeting was to multiply the standard deviation (shown in Table 1) by two for all invalid assays. The abnormal values occasionally produced by the on-line MATBAL could not be traced to the partial code listing given on November 2, which, when tested at CANMET still produced satisfactory results. It is our belief that another local modification exists in MATBAL as installed at Kidd Creek and without a complete listing, we cannot identify the cause of the observed abnormalities.

Table 1 Normal relative error model of assays (in %)

	Head	Cu Conc	Cu Tail	Zn Conc	Zn Tail
%Cu	5.0	2.5	5.0	5.0	5.0
%Pb	15.0	15.0	15.0	15.0	15.0
%Zn	5.0	10.0	10.0	2.5	5.0
%Fe	15.0	15.0	15.0	15.0	15.0

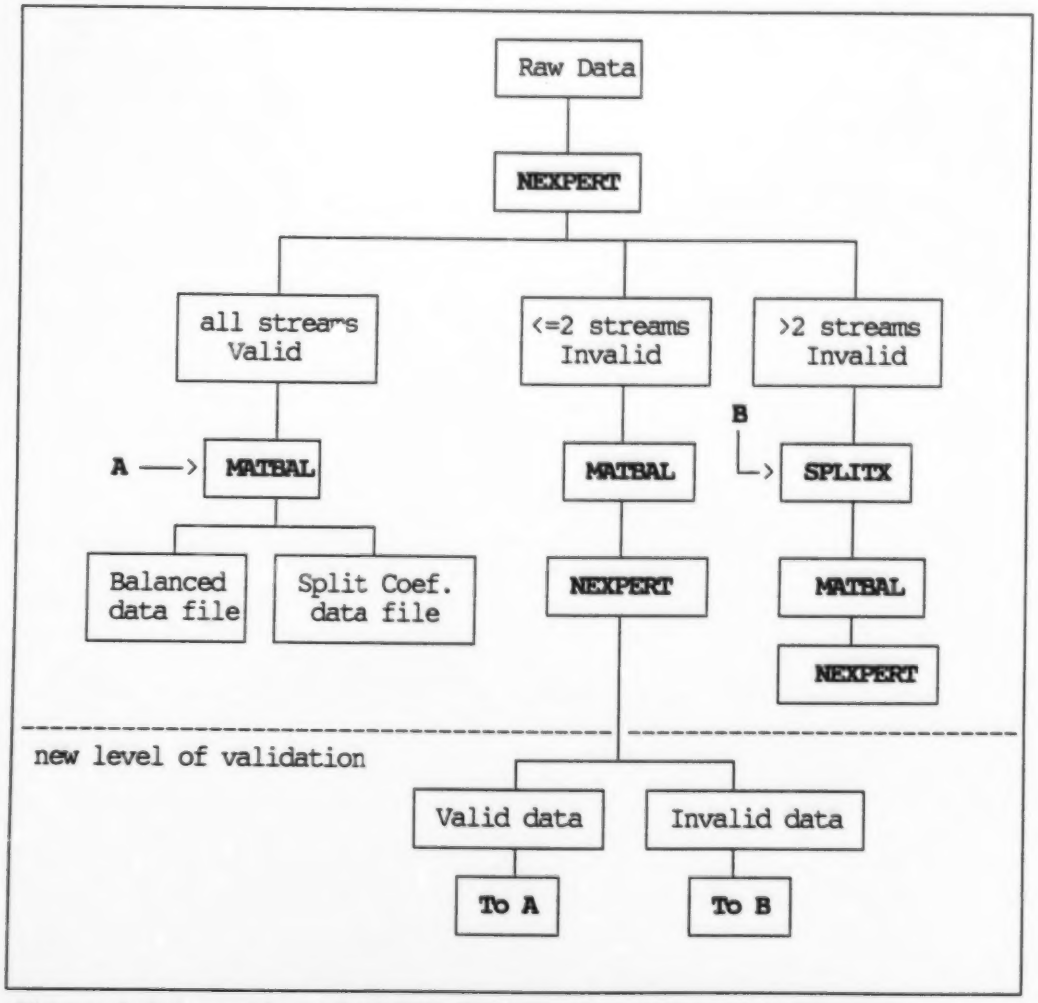

Figure 3 Interaction of MATBAL/SPLITX algorithms with NEXPERT knowledge base (with new level of validation)

RESULTS OF LATEST ALGORITHM TESTING

The testing performed on the algorithm confirms the initial findings reported in July,1988 when the modified MATBAL and SPLITX were delivered. They are described below.

1) Substitution by MATBAL only

Production data for "B" division, April 6,1988, representing a day when all pulp densities of the head stream, Cu Concertrate and Cu Tail fell within acceptable limits (Figures 4,5 and 6). On that day, samples No.15 and No.16 of the Cu Concentrate (Figure 7) showed a rapid relative variation of 3.4% in %Cu, which is above the 2.5% limit preset in Table 2 where the acceptability criterion is set for the relative variation. Rapid relative variations between the two samples are also noticed for %Cu and %Zn in Cu Tail (Figures 8 and 9). Table 3 shows actual relative variations between No.15 and No.16 for all assays.

Table 2 Relative variation limits for comparison data
($100*(X_i-X_{i+1})/X_i$)

	Head	Cu Conc	Cu Tail	Zn Conc	Zn Tail
%Cu	5.0	2.5	15.0	15.0	
%Pb	10.0	7.0			
%Zn	3.0	15.0	6.0	3.0	10.0
%Fe	0.8			3.0	3.0

Table 3 Relative variations between samples No.15 and No.16 in "B" division April 6,1988

	Head	Cu Conc	Cu Tail	Zn Conc	Zn Tail
%Cu	3.3	3.4*	23.0*	1.6	0.0
%Pb	0.0	0.0	5.3	0.0	0.0
%Zn	1.3	14.0	9.6*	0.5	1.5

* exceed acceptability criterion

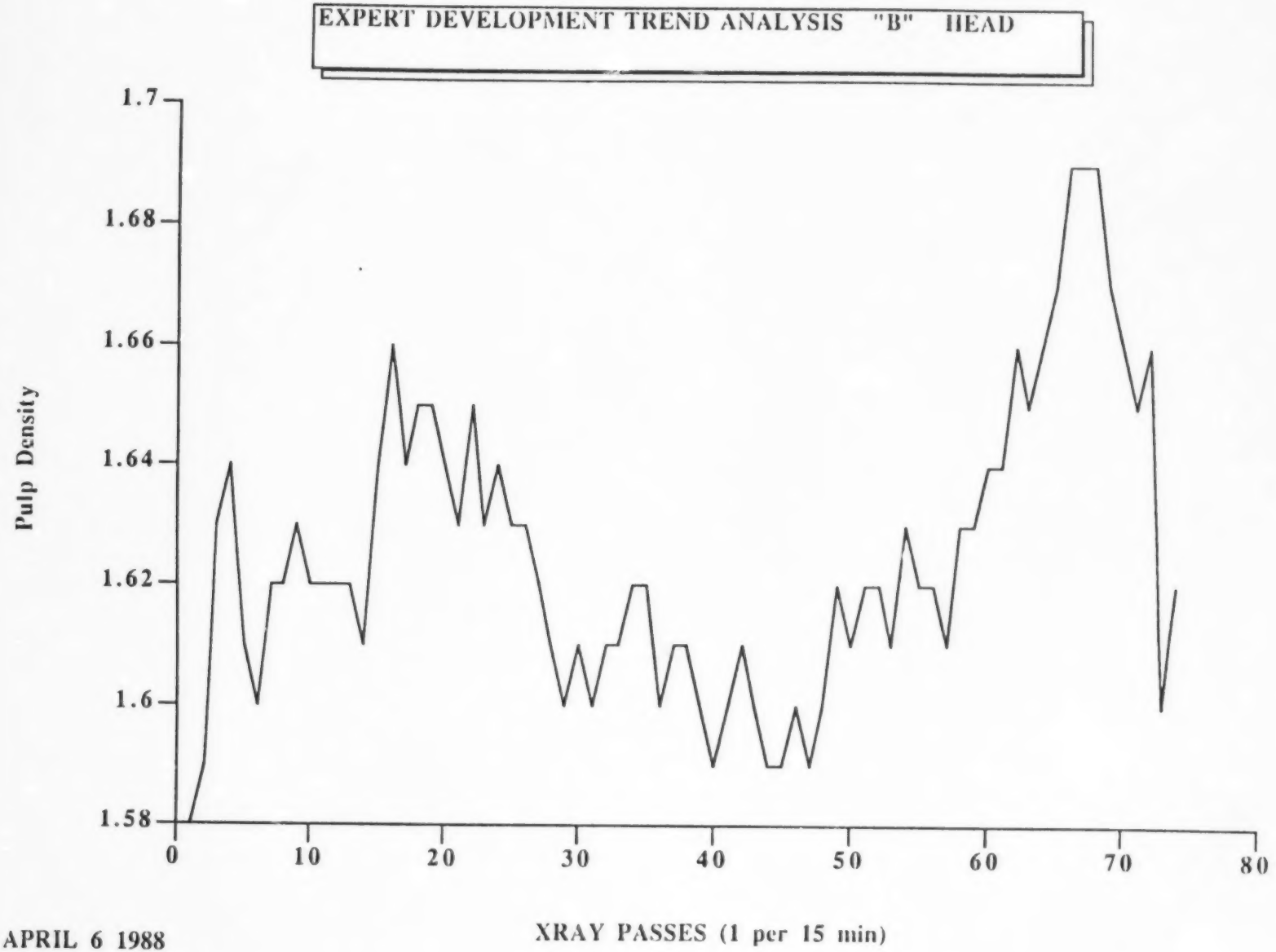

Figure 4. Pulp density in Head Stream

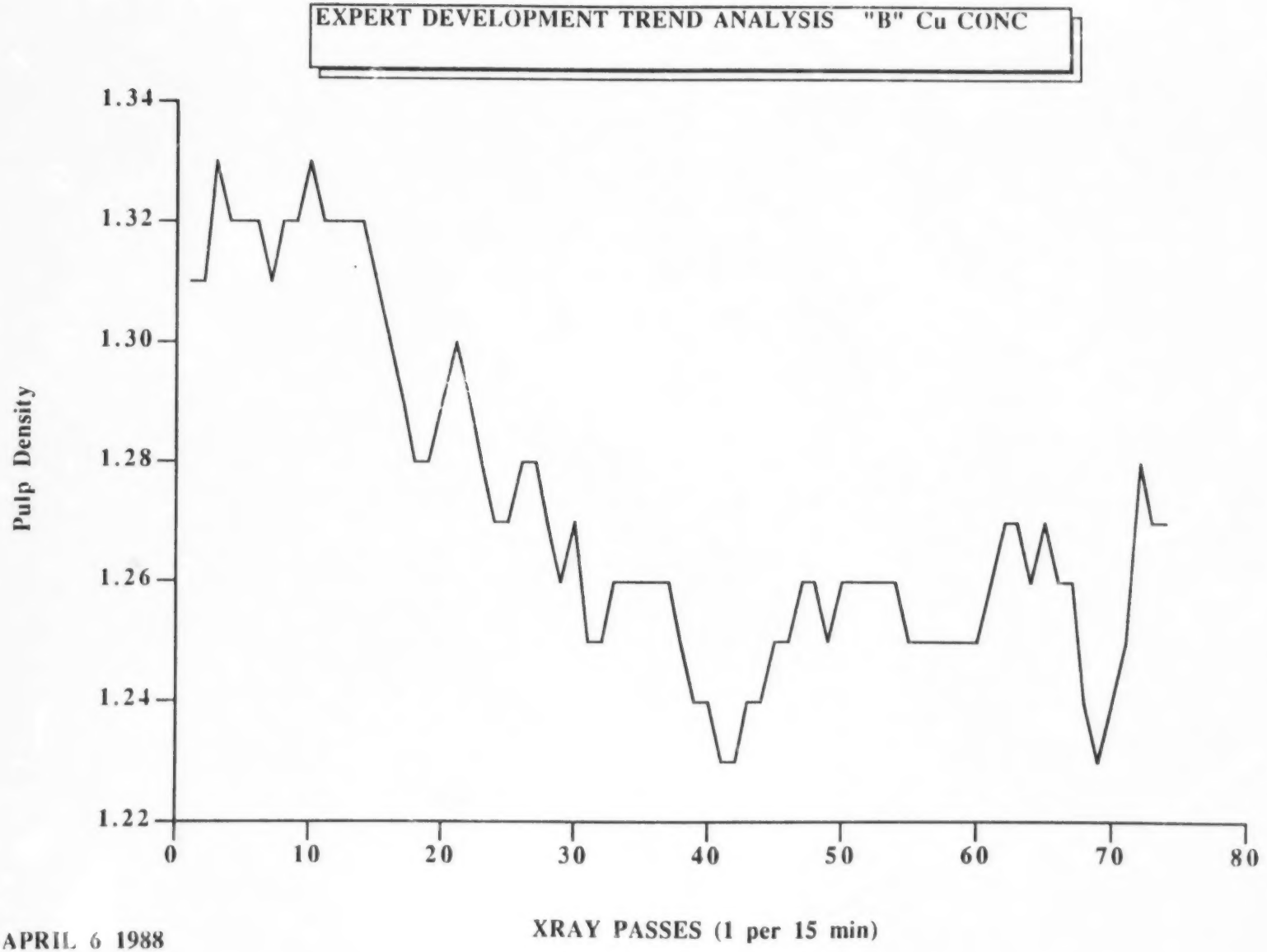

Figure 5. Pulp density in Cu Concentrate

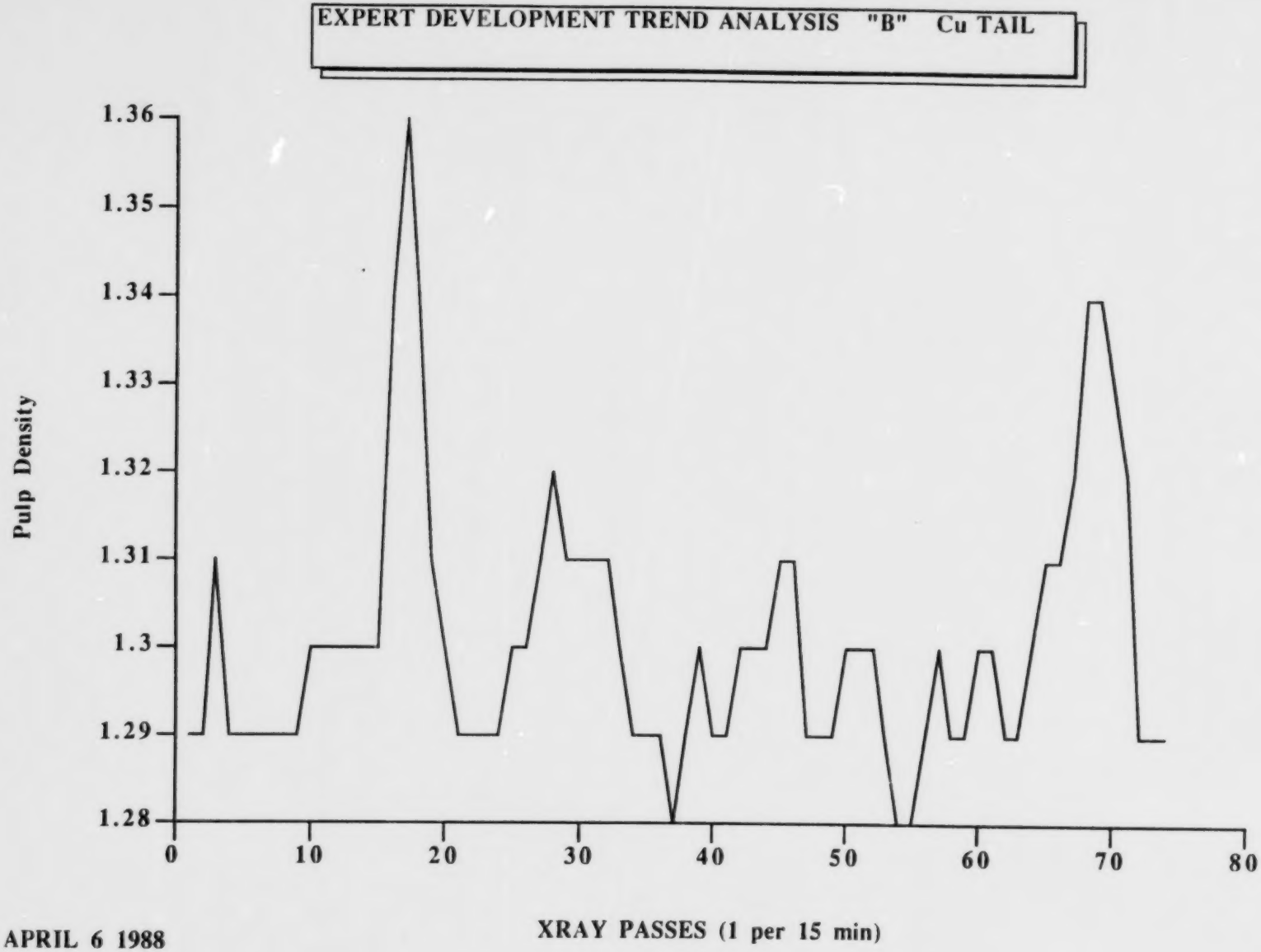

Figure 6 Pulp density in Cu tail

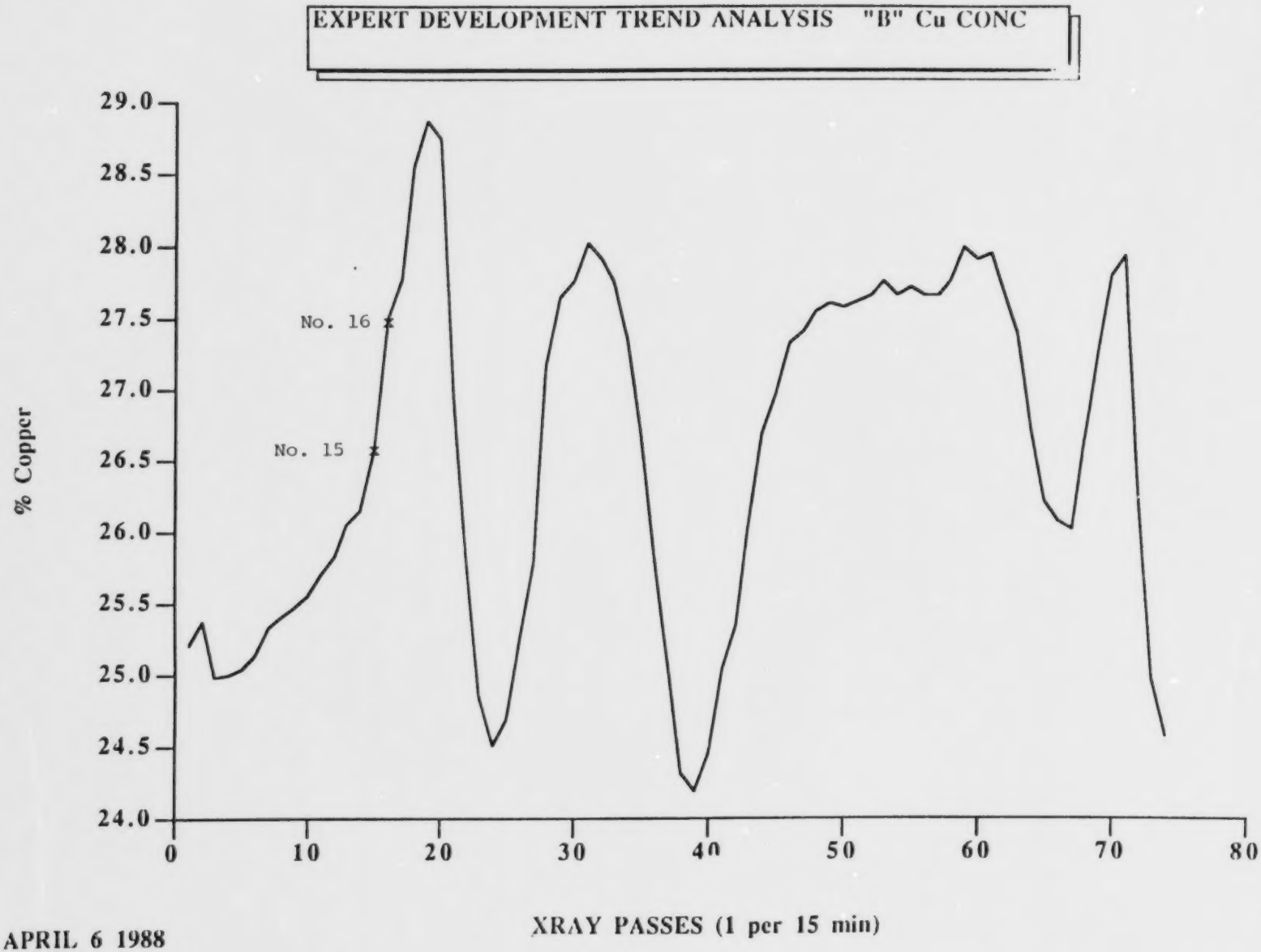

Figure 7 % Cu in Cu concentrate showing a rapid variation between Samples No. 15 and 16

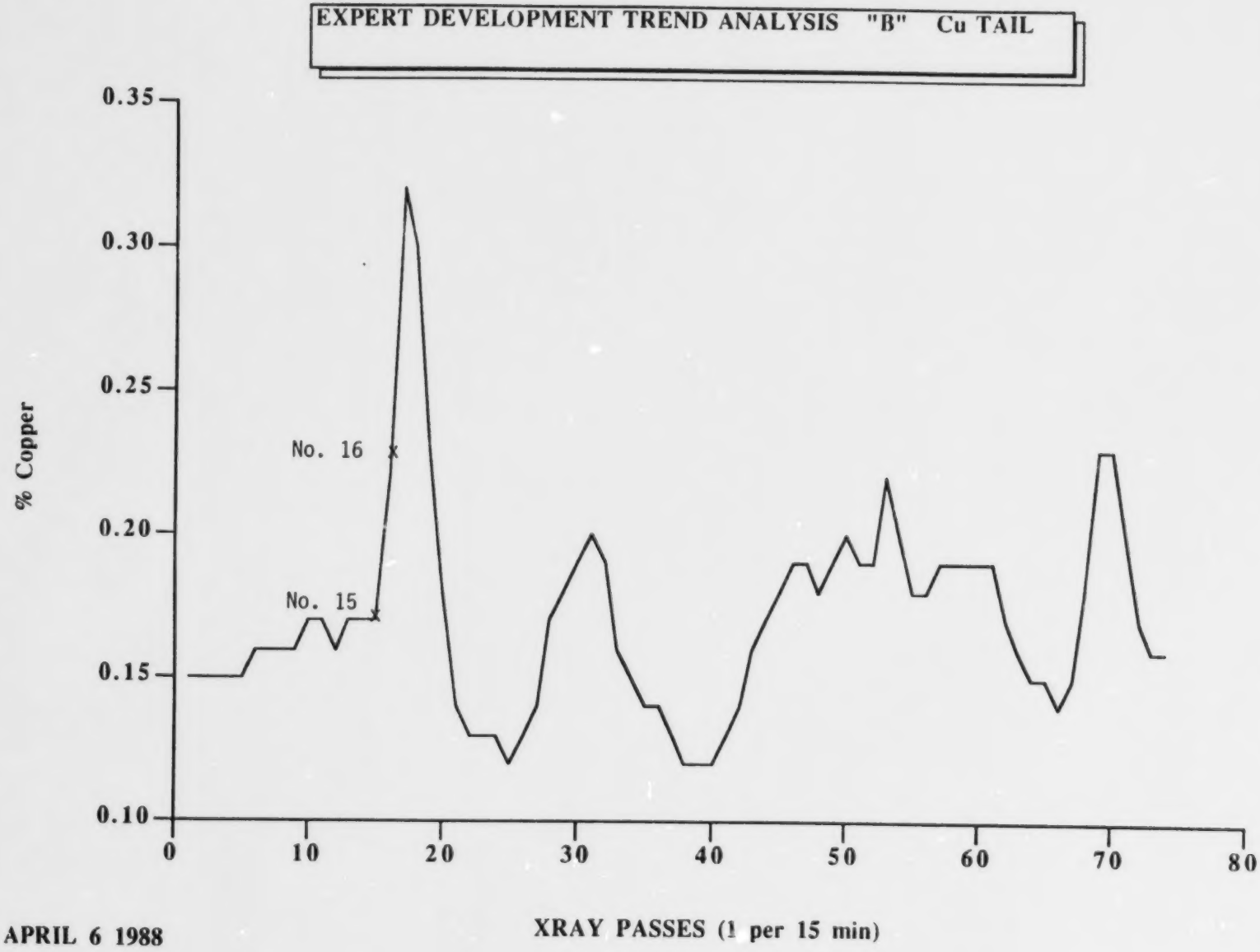

Figure 8 % Cu in Cu tail showing a rapid variation between samples No. 15 and 16

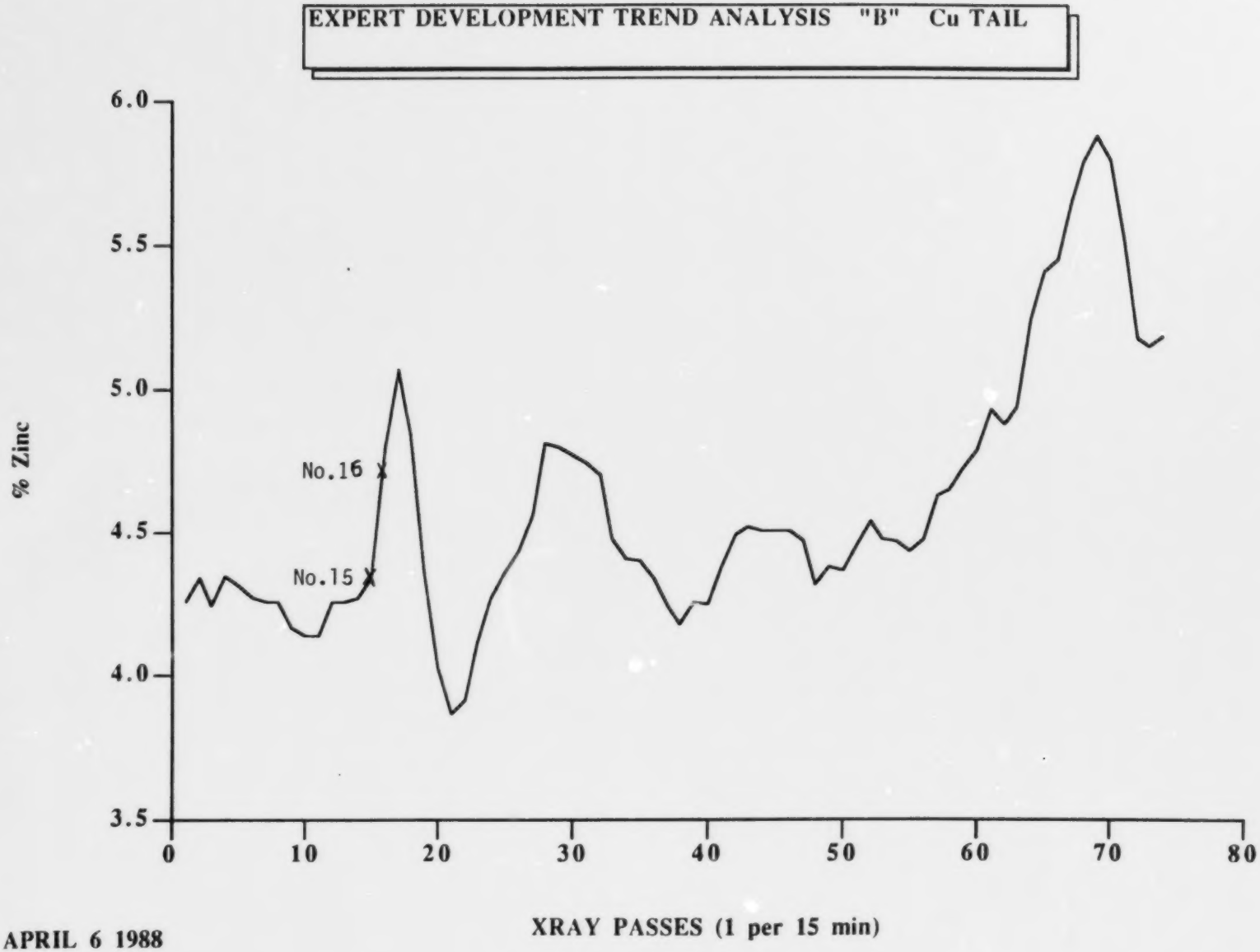

Figure 9 % Zu in Cu tail showing a rapid variation between sample No. 15 and 16

The variations for %Cu in Cu Concentrate and Cu Tail and for %Zn in Cu Tail are unacceptable. In order for a stream to pass the validity test, all assays in that stream must fall within the variation limits. Therefore, Cu Concentrate and Cu Tail are defined as invalid streams. This situation corresponds to the "MATBAL only" scenario for substitution. MATBAL was therefore executed with all valid data in No.16 sample plus the average value of the previous five valid samples (Nos.11 to 15) for Cu Concentrate and Cu Tail streams (%Cu, %Zn and %Pb in Table 4). Results from MATBAL shown in Table 5 show very little adjustment to the input assays. All calculated assays, when compared to sample No.15 pass the validity test for their relative variation.

Table 4 Assays of samples No.11 to No.15 and their average values

	Cu Conc.			Cu Tail		
	%Cu	%Pb	%Zn	%Cu	%Pb	%Zn
No. 11	25.71	1.04	3.02	.17	.02	4.14
No. 12	25.83	1.03	2.93	.16	.02	4.26
No. 13	26.05	1.03	2.83	.17	.02	4.26
No. 14	26.15	1.03	2.78	.17	.02	4.27
No. 15	26.57	1.00	2.58	.17	.02	4.34
average	26.06	1.03	2.83	.17	.02	4.25

Table 5 MATBAL result for sample No.16

	%Cu		%Pb		%Zn	
	Given	Cal.	Given	Cal.	Given	Cal.
Head	3.38	3.38	.14	.14	3.93	3.95
Cu Conc	26.06*	26.08	1.03*	.99	2.83*	2.81
Cu Tail	.17*	.16	.02*	.02	4.25*	4.11
Zn Conc	.62	.62	.03	.03	52.47	52.45
Zn Tail	.13	.13	.02	.02	.66	.66

* average values of previous 5 valid samples

It is important to note that the material balance of the two circuits involves 5 streams, 2 nodes and 3 assay types (Cu,Pb,Zn). MATBAL can therefore generate 8 equations (2 for solid, 2 per assay type) which are used to calculate 4 flowrates (since one of them is fixed). The minimum number of assays needed to solve the problem is 2, one in each circuit. This is why there are some degrees of freedom for guessing and altering all assays on two streams. Applying this scheme to more than two streams would run the risk of

running out of redundancy in some cases and produce meaningless results. The observation was made that the boundary check performed on assays has very broad limits (Table 6) and that most assays pass the test. The comparison check which examines the relative variations (Table 2) seems more likely to find invalid assays.

Table 6 Boundary limits of assays (absolute values in %)

	Head	Cu Conc	Cu Tail	Zn Conc	Zn Tail
Cu lower	2.0	20	0.1	0.4	
upper	5.0	29	0.3	1.5	
Abs. lower	0.5	15	0.05	0.2	
Abs. upper	9.0	33	1.0	4.0	
Pb lower	0.05	0.05	3.0	10.0	
upper	1.0	1.0	9.0	15.0	
Abs. lower	0.01	0.01	1.8		
Abs. upper	2.0	2.0	14.0		
Zn lower	3.0	1.0	3.0	50.0	0.5
upper	9.0	8.0	9.0	57.0	1.5
Abs. lower	1.8	0.5		40.0	0.3
Abs. upper	14.0	15.0		60.0	4.0
Fe lower	12.0			10.0	12.0
upper	19.0			15.0	19.0
Abs. lower	10.0			8.0	10.0
Abs. upper	21.0			17.0	21.0
Pulp Density					
lower	1.1	1.1	1.0	1.1	1.0
upper	1.7	1.6	1.4	1.6	1.4

2) **Substitution by SPLITX**

A test was done to simulate a scenario where all data, including head stream would be missing in sample No.16. The average split coefficients obtained from the last 5 MATBAL results on valid raw data were used to simulate all streams from a head composition obtained also by averaging the last 5 valid head assays (Table 7). Results are shown in Table 8. A comparison with Table 5 shows very close agreement and all simulated tests pass validity checks when compared to No.15. This seems to reduce fears that a missing head sample renders the substitution scheme unreliable, unless of course the last valid head sample is too old, a situation that is detected by NEXPERT.

Table 7 Split coefficients and Head assays of samples No.11 to No.15 and their average values

	Head assays			Split Coefficient					
				Cu Conc.			Cu Tail		
	%Cu	%Pb	%Zn	%Cu	%Pb	%Zn	%Cu	%Pb	%Zn
No. 11	3.20	.14	4.00	.9542	.8725	.0890	.2604	.1036	.8770
No. 12	3.22	.14	4.00	.9556	.8722	.0870	.2629	.1016	.8566
No. 13	3.26	.14	3.96	.9552	.8725	.0841	.2565	.1003	.8459
No. 14	3.35	.14	4.03	.9562	.8743	.0836	.2656	.1029	.8574
No. 15	3.49	.14	3.98	.9582	.8747	.0803	.2633	.1019	.8529
average	3.30	.14	3.99	.9559	.8732	.0848	.2617	.1021	.8580

Table 8 SPLITX result: simulated sample No.16

	%Cu	%Pb	%Zn
Cu Conc	26.05	1.01	2.79
Cu Tail	.17	.02	4.15
Zn Conc	.62	.03	51.37
Zn Tail	.13	.02	.63

DISCUSSION

The above tests indicate that the proposed substitution algorithm performs adequate data replacement in both cases when MATBAL alone or MATBAL and SPLITX are used. It is also worth noting that after sample No.16 was corrected and passed the comparison check with No.15, the next comparison is made between No.17 and the corrected No.16. This may force No.17 to be substituted when it would not have been found invalid if compared to the original No.16. No clear disadvantage was found to this effect, which happens in zones of rapid assay fluctuations and makes assays more suspect. This cumulative effect is illustrated in Figure 10, where the moving average has been plotted.

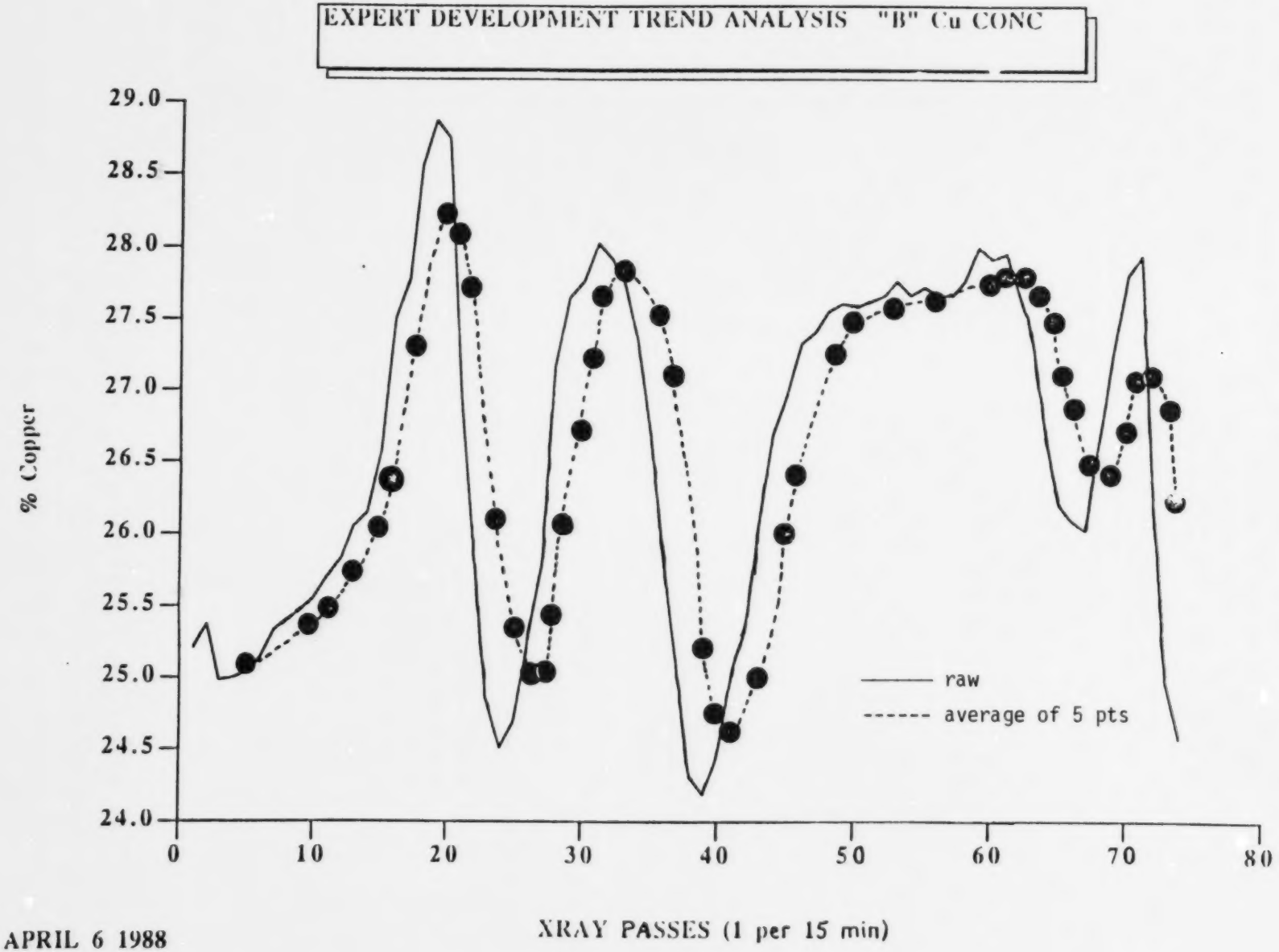

Figure 10. % Cu curve and its moving average of last 5 points

CONCLUSION

The algorithm for numerical data substitution in the Kidd Creek Expert System, using CANMET's modified MATBAL and SPLITX has been shown to perform satisfactorily off-line. In the code delivered to Kidd Creek in July, 1988, a driver has been included that automatically performs the material balance adjustment of the assays supplied in a sequential input file until an "end of file" is encountered. For each balance, the adjusted assays and calculated split coefficients are added sequentially to 3 files as described. The SPLITX program is activated by a driver that reads the split coefficients produced by MATBAL and the head assays in two separate files. The simulated assays are written by SPLITX in two separate files, one for the Cu circuit and the other for the Zn circuit. The SPLITX driver is interrupted when an "end of file" is encountered. We recommend that this algorithm be imbedded on-line in the testing of the data validation expert system.

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